AIRBORNE COLLECTION OF LEONID DUST DURING THE 2002 NOVEMBER METEOR STORM: WHAT TO LOOK FOR.

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Introduction. For almost three decades, collectors borne underneath the wings of high-flying aircraft in the lower stratosphere between 17-19 km altitude have collected interplanetary dust particles (IDPs) that are the solid debris of comets and asteroids. They survived flash-heating during deceleration on atmospheric entry because the product of their diameter and density was just right to avoid evaporation. That is, they avoided becoming a shooting star. Some fraction of the debris survives as IDPs. The collected chondritic aggregate IDPs, while heated, did not melt and thereby preserved much of the original mineralogical and chemical properties of the parent comet or asteroid 'intact'. In between these extreme cases there is a sizeable group of IDPs that melted but were quenched before they have completely ablated. These surviving IDPs are spheres with 'silicate' and Fe(±S) compositions. All else being equal, i.e. the size-density product and atmospheric entry angle, survival, melting or evaporation is a function of increasing meteoroid entry velocity. With an average entry velocity at ~11 km/s dust from asteroids have a much better change surviving as 'intact' IDPs than comet dust at velocities >20 km/s. With increasing velocity, i.e. more comet-like, surviving debris will be IDP spheres. And because mass-loss during ablation is a function of entry velocity only initially large comet meteoroids survive as spheres. The current models predict only the slimmest chance for Leonid debris, that at ~72 km/s are the fastest moving dust entering the Earth's atmosphere, to survive as collectable IDPs.

What we know: NASA Cosmic Dust Program. This program offers a fair, but not necessarily exact, representation of the types and sizes (mostly ~10 to ~100 microns in diameter) of dust that annually enters the atmosphere. A survey of the Cosmic Dust Catalogs showed that the number of silicate spheres mimics the sporadic meteor background. Two peaks in the sphere abundances are coincident with the activity of annual meteor streams of comets Swift-Tuttle and Halley and the comets Halley and Tempel-Tuttle, the source of Leonid meteors, during the Fall (Figure 1). The Table shows the properties of the 20-30 micron-sized 'silicate' spheres collected at the times of the Orionid and Leonid meteor showers, *but not a Leonid storm*, in the fall. During this collection period the IDPs also included the highest number of Fe(±S) spheres recorded by this program at any other times of the year. The summer silicate peak did not include any FeS IDPs.

Composition	Particle Type	Relative abundance (%)
Mg,Si±Fe	olivine; pyroxene	27
Mg,Si,Ca±Al	Ca-rich pyroxene; fractionation residue	55
Al,Si,Ca	Plagioclase; fractionation residue	18

Assuming they are ablated, quench-melted, Leonid debris, the 2002 storm will include 60% silicate' spheres, dominated by Mg,Si,Ca±Al spheres, and 40% FeS spheres. Highly refractory compositions might be present depending on the fractionation process during ablation.

What we know of the current Leonid storm. The NASA Cosmic Dust Program had a dedicated flight during the 2000 Leonid storm. While detailed analysis of the collected dust has not yet been completed, a preliminary finding shows an unusually high number of spheres (Curator of Cosmic Dust, pers. comm.). But, a crucial observation was the finding of a solid mass at the ending of some luminous Leonid meteor trails. The millimeter-sized meteoroid had a temperature of <450K to 600-700K at 115 km altitude, which is still well below the melting point of silicates and FeS. This surviving debris was seen as low as 73 to 56 km altitudes when it was not further detected. In one case the original meteor mass was estimated at 1 kg, i.e. ~12 cm in diameter. While still traveling at 90 – 85% of the initial velocity, deceleration in a denser atmosphere could ultimately yield a spherical ‘silicate’ IDPs of several hundreds of microns in diameter, most likely 50-100 microns, but as small as ‘silicate’ spheres discussed above. Any ‘silicate’ spheres survived after extreme mass loss close to 100% of originally mm- to cm-sized Leonid meteoroids. They might show extreme chemical fractionation with strongly enhanced refractory element abundances.

How many spheres in a storm? Some fraction of the incoming Leonid meteoroids will survive as spheres that will cause a sharp peak in the number of mostly silicate spheres, and a smaller number of FeS spheres, in the lower stratosphere. Based on gravitational settling rates for spheres we might expect encountering a ‘high’ number of spheres >100 microns in diameter during the time of the two peaks of the 2002 Leonid storm. The first peak over Europe has 5,900 meteors from dust that was released from the comet in 1767. The second peak over the U.S. is caused by dust released in 1866. This peak will include 5,400 meteors. If only 1‰ of the 11,300 meteors would survive as spheres, this number would match the number of spheres from the peak in the annual Orionid/Leonid showers. The collection efficiency during this shower peak was 0.0105 dust particles/collector area/hour ($p/cm^2/h$) in the lower stratosphere, which corresponded to eleven collected ‘silicate’ spheres. This factor applies to shower activity; not to the enhancement of a Leonid meteor storm. Using this shower efficiency factor for 5-30 micron-sized spheres, we anticipate collecting at least two (2) to three (3) ‘silicate’ spheres during an 8-hour collection period, which is the minimum time of stratospheric flight during the 2002 storm. Only three collected spheres would mean that our collection experiment was inconclusive with regard to establishing a unique link to the Leonid storm; we merely duplicated the NASA experiment.

More collected ‘silicate’ spheres spells success, i.e. they include Leonid storm debris. It is not an unrealistic expectation because even a very-low Leonid storm meteoroid survival rate of 1% yields 113 collectable IDPs.

Conclusion. The next opportunity for a similar Leonid experiment will not occur until the 2099 storm. We expect to collect more than three Leonid meteor ablation spheres that are probably mostly ~100 micron-sized ‘silicate’ spheres during the 2002 Leonid MAC campaign using a collector located near the front of the aircraft. This aircraft will follow the peaks in the storm when flying from Spain to the US. The time between this collection opportunity and the shower peaks is too small for the global dispersion of surviving Leonid dust but sufficient for settling of the larger spheres. This situation differs from the NASA Cosmic Dust Program wherein the flights were not deployed as targeted collection opportunities. Our 26-cm^2 collector is comparable to the 30 cm^2 (normalized) NASA collectors. The storm meteor enhancement will offset our lower collection time of ~25% of a NASA flight. Our successful experiment will be the first collection of stratospheric IDPs with a direct link to a particular source. In our case that is short-period comet Tempel-Tuttle. With success for the ultrafast Leonids we will have shown the feasibility of collecting cometary debris in the stratosphere using targeted opportunities.

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Figure 1: Number of ‘silicate’ spheres in the NASA Cosmic dust Program between 1981 May and 1994 July. The first ‘peak’ above the sporadic meteor background (dashed curve) includes the annual showers of comets Swift-Tuttle and Halley during the summer. The second peak during the Fall includes another annual comet Halley shower and Leonids shower from comet Tempel-Tuttle.